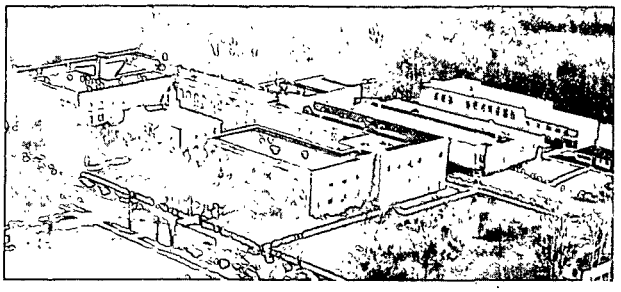
Carl Smith



THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

STACKING LIFE OF CORRUGATED BOXES IN RELATION TO BOX DIMENSIONS AND COMBINED BOARD PROPERTIES

Project 2695-2

Report One

A Preliminary Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

January 30, 1968

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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INTRODUCTION

In a past study for the Fourdrinier Kraft Board Institute, Inc., it was found that there were large and significant differences in stacking life between the box lots studied. At a constant applied load ratio, the box size and construction giving the highest stacking life exceeded the performance of the poorest box sample by a ratio of 30 or 40 to 1. In general, the differences in stacking life appeared to depend, in part, on box dimensions and combined board edgewise compression.

Because these results were unexpected, the FKBI authorized a supplementary study of box and combined board stacking life to extend the previous results to additional box constructions and sizes. The supplementary study was initiated in 1967 and will be completed in 1968. This interim report briefly summarizes the status of the work and results obtained to date.

MATERIALS

Seven box constructions were selected for the study and five samples have been received to date. The remaining two samples are expected to arrive in the near future. The characteristics of the box samples received are tabulated in Table I. As may be noted, there are two single-wall and three double-wall constructions under test. The two boxes to be received will be made from 200-lb. series C-flute and 350-lb. series B-flute board.

DISCUSSION OF RESULTS

BOX STACKING LIFE

The results obtained at 50% R.H. are tabulated in Table II and graphically illustrated in Fig. 1. With the exception of a few tests in progress at the lower load ratios, the tests are nearly complete on these five box lots. As set forth in the proposal, the loads were selected in so far as possible to limit test durations to about 100 days. In general, this objective has been attained although tests were continued to longer durations in a few instances.

As noted in Fig. 1, the 275- and 500-lb. series double-wall constructions (Lots 71 and 12) gave materially shorter stacking lives than the other constructions. In the case of the 500-lb. series boxes, it was observed that the broad flap scorelines resulted in appreciable rolling of the scorelines at the top and bottom. This is also indicated by the large deflection (1.60 inch) at maximum load for this box. As a result of the "scoreline rolling," the side walls of the box were forced to bow in and this may account, in part, for the relatively short failure lives. In this case the presence of inner partitions,

TABLE I

CHARACTERISTICS OF BOXES AND COMBINED BOARD

No.	Flute	Series	Size (l x w x d)	Top-Load Compression Max. Load lb.	Top-Load Compression Defl., in.	Basis Weight, lb./M ft.^{2}	Caliper, pt.	Edgewise Compression, lb.	Flexural Stiffness, lb./in. In	Flexural Stiffness, lb./in. Cross
2	C	175	9.5x9.12x6.75	495[a]	0.37[a]	114	153	37.4	105	49
3	A	350	19.0x13.0x21.25	1700[a]	0.89[a]	229	222	79.0	521	198
71	CB	275	20.0x20.0x12.0	1620	0.80	199	267	77.1	404	165
27	CB	350	20.0x15.0x25.0	1435[b]	0.87[b]	208	278	69.4	433	152
12	CB	500	20.25x15.12x25.0	2225[b]	1.60[b]	313	277	97.2	562	330

[a] Multipeaked load-deflection curves. The load and deflection at first peak were 1430 lb. and 0.66 in., respectively.

[b] Multipeaked load-deflection curves. The load and deflection at first peak were 985 lb. and 0.88 in., respectively.

TABLE II

SUMMARY OF BOX STACKING RESULTS AS OF JAN. 22, 1967

No.	Box Description	Test No.	0.85 Load Ratio Life, Day	0.85 Load Ratio Defl., in.	0.80 Load Ratio Life, Day	0.80 Load Ratio Defl., in.	0.75 Load Ratio Life, Day	0.75 Load Ratio Defl., in.	0.70 Load Ratio Life, Day	0.70 Load Ratio Defl., in.	0.65 Load Ratio Life, Day	0.65 Load Ratio Defl., in.	0.60 Load Ratio Life, Day	0.60 Load Ratio Defl., in.
7002	175-lb. series, C-flute, 9.5x9.12x6.75 in.	1					0.84	0.34	3.5	0.40	64.3	0.39	164.7	0.40
		2					3.0	0.35	17.8	0.40	70.2	0.40	190.6	0.40
		3					8.0	0.38	12.0	0.35	30.6	0.37	129.6	0.39
		4					9.9	0.39	19.2	0.39	58.8	0.40	129.0	0.42
		Av.					5.4	0.36	13.1	0.38	56.0	0.39	153.5	0.40
		Median					5.5		14.9		61.6		147.2	
7003	350-lb. series, A-flute, 19x13x21.25 in.	1	0.105	1.11	2.3	0.99	4.5	1.43	43.6	1.43	116.7	0.92	209.7[e]	0.98
		2	0.004	0.95	0.031	0.68	4.5	0.96	31.5	1.09	98.6	0.91	IP(224)	--
		3	0.048	0.96	0.180	0.99	18.6	1.02	52.2[c]	0.89	3.6	1.43	--	--
		4	0.062	0.89	0.056	1.02	6.6	1.05	4.5[b]	1.32	90.6	0.96	--	--
		Av.	0.055	0.98	0.64	0.92	8.6	1.12	33.0	1.18	77.4	1.06		
		Median	0.055		0.12		5.6		37.6		94.6			
7012	500-lb. CB double-wall, 20.25x15.12x25.0 in.	1	--[a]	--[a]	--[a]	--[a]	0.046	1.74	0.59	1.75	0.039	1.54	117.6[d]	1.69
		2	--[a]	--[a]			0.038	1.64	8.7	1.74	2.9[g]	1.74	72.6	0.79
		3					0.260	1.64	1.6	1.60	14.7	1.81	IP(60)	
		4					0.262	1.60	1.7	1.72	16.0	1.93	IP(8)	
		Av.					0.152	1.66	3.1	1.70	8.4	1.76	95.1	1.24
		Median					0.153		1.6		8.8			
7027	350-lb. CB double-wall, 20.00x15.00x25.0 in.	1	0.256	0.77	0.110	0.84	15.7	0.91	18.0	0.92	21.5	0.89		
		2	0.001	0.77	0.458	0.74	3.0	0.77	33.5	0.88	104.1	0.76		
		3	0.124	0.87	6.000	0.83	5.6	0.78	38.6	0.87	IP(113)			
		4	0.011	0.70	0.240	0.75	8.5	0.77	9.1	0.74	IP(8)			
		Av.	0.098	0.78	1.70	0.79	8.2	0.81	24.8	0.85	62.8	0.82		
		Median	0.068		0.35		7.0		25.8					
7071	275-lb. series, CB double-wall 20.0x20.0x12.0	1			0.048	0.81	0.038	0.82	2.45	0.83	6.62	0.78	IP(29)	
		2			0.051	0.80	0.034	0.76	1.65	0.77	33.4	0.84	IP(29)	
		3			0.075	0.85	0.285	0.77	2.07	0.92	18.9	0.84	IP(7)	
		4			0.087	0.82	0.309	0.83	3.59	0.77	IP(38)		IP(7)	
		Av.			0.065	0.82	0.166	0.80	2.44	0.82	19.64	0.82		
		Median			0.063		0.162		2.26					

[a] Boxes failed almost immediately after application of load.

[b] Poor adhesion noted on double-face side.

[c] During the test a horizontal crease appeared on one panel and box failed along crease.

[d] Adhesion on manufacturers joint failed.

[e] Poor adhesion along flap scores.

Note: Tests in progress designated by "IP"; value in parenthesis indicates number of days the test has been in progress.

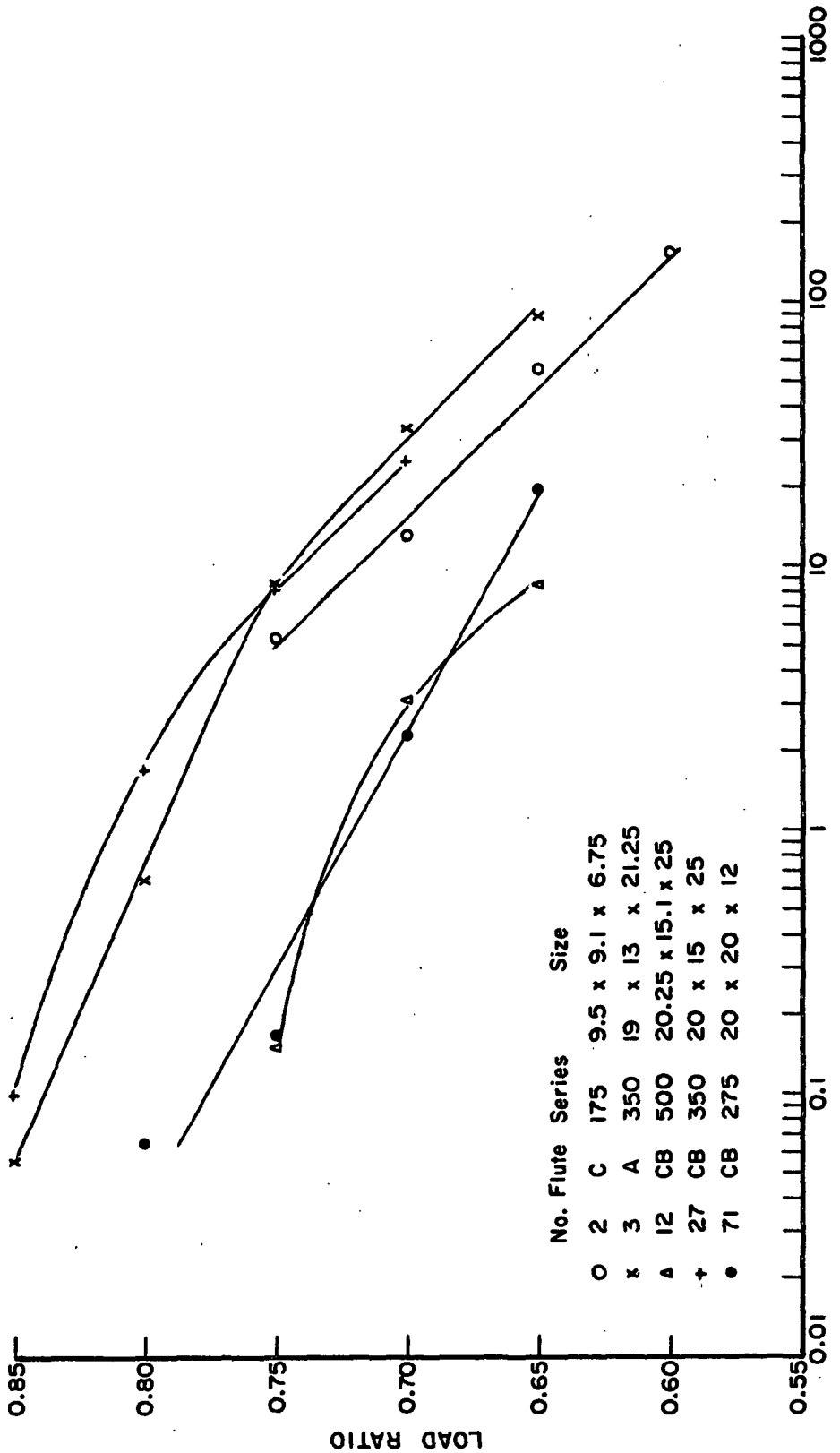

Figure 1. Relationship Between Load Ratio and Stacking Life for Boxes

commodity, etc. to restrain the inward bowing would be expected to result in longer stacking lives.

In Fig. 1 it also may be noted that the load ratio vs. stacking life relationship becomes curvilinear in most instances when tests are carried out at the higher load ratios (shorter time durations). This behavior was previously reported by Kellicutt and Landt (1). In metals, the change in curve slope is generally attributed to a change in failure mechanism – i.e., from a ductile to brittle fracture. These mechanisms would not be expected to account for the change in curve shape for corrugated boxes. The question may be somewhat academic because the interest in box behavior is centered on the longer time durations; however, analysis of the data will require some consideration of the curve shape.

In the near future it is planned to evaluate the stacking lives of three of the box samples (Lots 2, 3, and 27) at 90% R.H. and 73°F. A load ratio of 0.75 will be employed. These tests together with the evaluation of the two box lots to be received should be complete by late spring.

COLUMN CREEP LIFE

The results to date are summarized in Table III and illustrated in Fig. 2. It may be noted that these tests are nearing completion and it is anticipated that all tests will be completed by early summer. In general, the results follow much the same pattern as the results obtained in the first phases. There are differences between lots; however, the differences have not been tested statistically pending completion of the testing.

TABLE III

SUMMARY OF COLUMN CREEP RESULTS AS OF JAN. 22, 1967

No.	Board Description	Test No.	0.75 Load Ratio Life, day	0.75 Load Ratio Defl., in.	0.70 Load Ratio Life, day	0.70 Load Ratio Defl., in.	0.625 Load Ratio Life, day	0.625 Load Ratio Defl., in.
7002	175-lb. series, C-flute	1	0.26	0.031	13.6	0.028	134.6	0.030
		2	0.017	0.020	2.56	0.022	IP(63)	
		3	0.28	0.021	0.06	0.020	2.9	0.025
		4	0.38	0.027	0.16	0.022	52.6	0.029
		Av.	0.23	0.025	4.08	0.024	63.4	0.028
		Median	0.27		1.36			
7003	350-lb. series, A-flute	1	2.0	0.039	0.17	0.023	30.6	0.033
		2	0.071	0.036	1.11	0.039	79.1	0.033
		3	1.6	0.042	0.34	0.038	IP(2)	
		4	0.13	0.032	5.63	0.040		
		Av.	0.95	0.037	1.81	0.035	54.8	0.033
		Median	0.86		0.72			
7012	500-lb. series, CB double-wall	1	2.4	0.034	2.7	0.040	109.1	0.047
		2	0.05	0.032	0.41	0.028	118.1	0.046
		3	0.10	0.034	4.9	0.039	16.8	0.036
		4	0.03	0.023	40.5	0.039	5.6	0.038
		Av.	0.64	0.031	12.1	0.036	62.4	0.042
		Median	0.08		3.80		63.0	
7027	350-lb. series, CB double-wall	1	0.69	0.029	1.37	0.029	43.9	0.038
		2	0.32	0.034	0.18	0.026	IP(60)	
		3	0.69	0.034	0.87	0.029	IP(4)	
		4	1.47	0.034	1.68	0.037		
		Av.	0.79	0.033	1.02	0.030		
		Median	0.69		1.12			
7071	275-lb. series, CB double-wall	1	2.46	0.030	0.12	0.026	1.44	0.021
		2	0.02	0.025	3.48	0.027	18.0	0.031
		3	0.57	0.024	0.46	0.022	16.8	0.025
		4	0.84	0.032			2.25	0.025
		Av.	0.97	0.028	1.35	0.025	9.62	0.026
		Median	0.70				9.52	

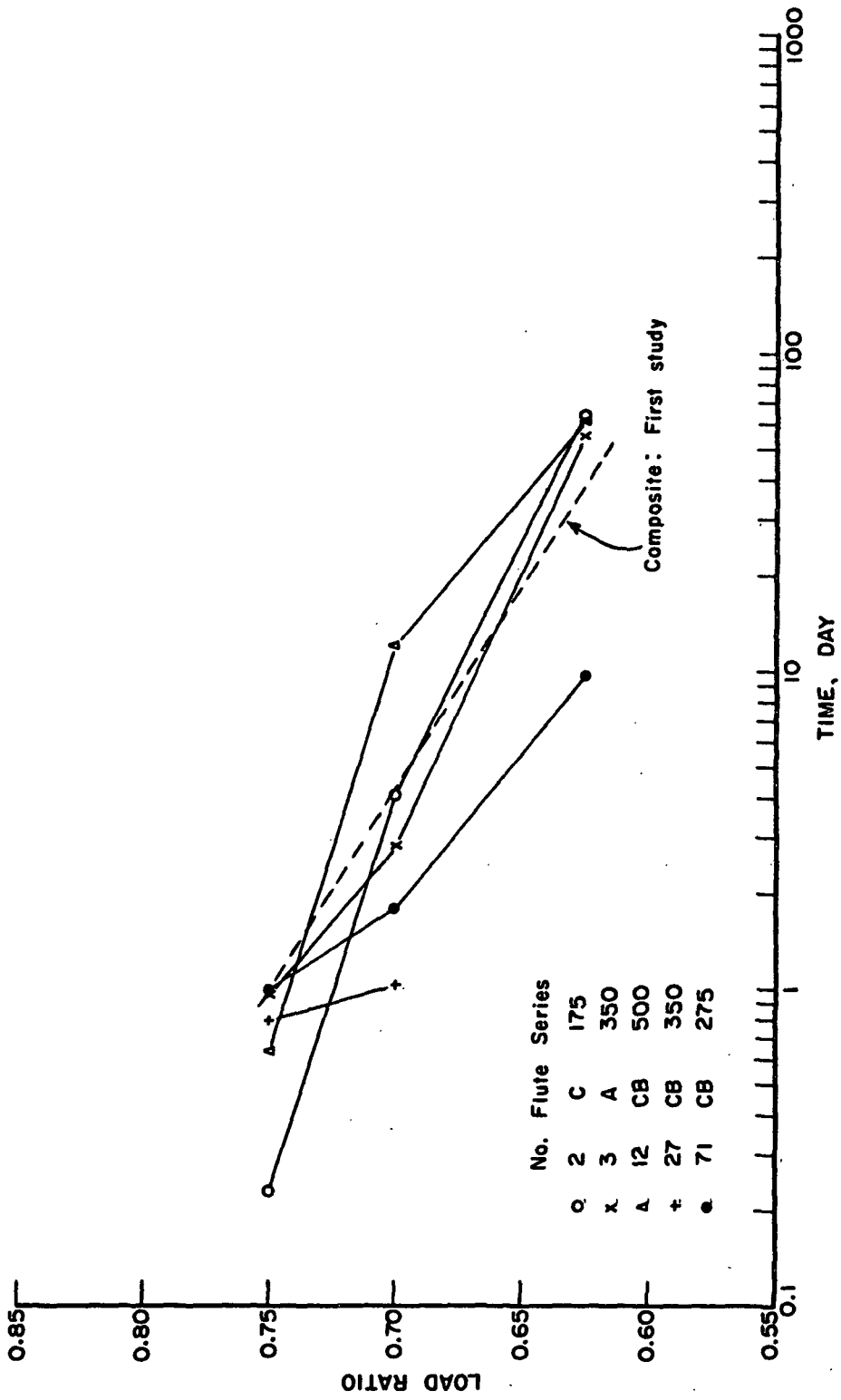

Figure 2. Relationship Between Load Ratio and Short Column Stacking Life

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1. Kellicutt, K. Q., and Landt, E. F., Fiber Containers 36, no. 9:28, 30, 35-6, 38 (Sept., 1951).

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